Mild hypothermic (30°C) body perfusion during replacement of the aortic arch with a novel arterial perfusion cannula

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Complex aortic arch procedures pose significant challenges to the cardiac surgeon, as well as significant morbidity to the patient. Different techniques for preservation of cerebral and distal organ function have been demonstrated.[1-3] Numerous publications have suggested using total circulatory arrest with systemic temperatures of less than 18°C, but this method can be associated with long operation times and severe coagulation disorders. More recently, antegrade cerebral perfusion has generated increasing interest because it allows aortic arch operations at mild hypothermia.[4] For complex procedures, preservation of spinal cord and abdominal organ function remains a problem with this technique, possibly leading to postoperative acute renal failure, neurological deficits, or malfunction of intestinal organs.

This work describes our initial experience with a new perfusion cannula, allowing perfusion of cerebral vessels and the descending aorta with one cannula (Figure 1). This perfusion setup enables "warm" arch surgery with optimal brain and distal organ perfusion, avoiding circulatory arrest with attention to comfortable conditions at the distal anastomosis of the aortic arch.

Surgical Technique

Patients are positioned supine on the operating table with the right upper extremity in close proximity to the body. After induction of anesthesia and tracheal intubation, the left radial artery and left femoral artery are cannulated for blood pressure monitoring. A transesophageal echocardiographic probe is placed. Temperature is monitored through esophageal and rectal sensor probes.

After systemic heparinization (300 IU/kg), the right subclavian artery is exposed and cannulated with an 18F to 22F flexible arterial cannula designed by Dr Aybek. After median sternotomy, the right atrium is cannulated with a double-stage venous cannula

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TABLE 1. Patient demographics

Demographics	N = 10
Male subjects	7
Female subjects	3
Age (mean ± SD)	62 ± 17
CAD	2
AR > 1°	2
Rupture	4
Renal insufficiency	3
COPD	3
Cerebrovascular disease	2
Redo	1
Cause	
Hypertension	9
Marfan syndrome	1

SD, Standard deviation; *CAD*, coronary artery disease; *AR*, aortic valve regurgitation; *COPD*, chronic obstructive pulmonary disease.

TABLE 2. Perioperative data

Surgical approach	
Median sternotomy	5
Transverse thoracotomy (clamshell)	5
Operative procedure	
Asc + arch	2
Asc + arch + descendens	8
Additional procedures	
Aortic valve replacement	1
Aortic valve sparing	1
CABG	2
Operative data	
Operative time (min)	266 ± 48
CPB time (min)	136 ± 42
Myocardial ischemic time (min)	94 ± 69
Isolated cerebral perfusion time (min)	48 ± 29
Cerebral perfusion flow (mL/min)	1410 ± 80
Cerebral perfusion temperature (°C)	31.2 ± 1.0
Core temperature (°C)	31.4 ± 0.6
Postoperative course	
ICU stay (d)	2.4 ± 4.5
Ventilation time (h)	12 ± 10
Hospital stay (d)	14 ± 10
Mortality (30 d)	1 (10%)
Temporary neurological dysfunction	0
Permanent neurological deficit	0

Asc, Ascending aorta; *CABG*, coronary artery bypass grafting; *CPB*, cardiopulmonary bypass; *ICU*, intensive care unit.

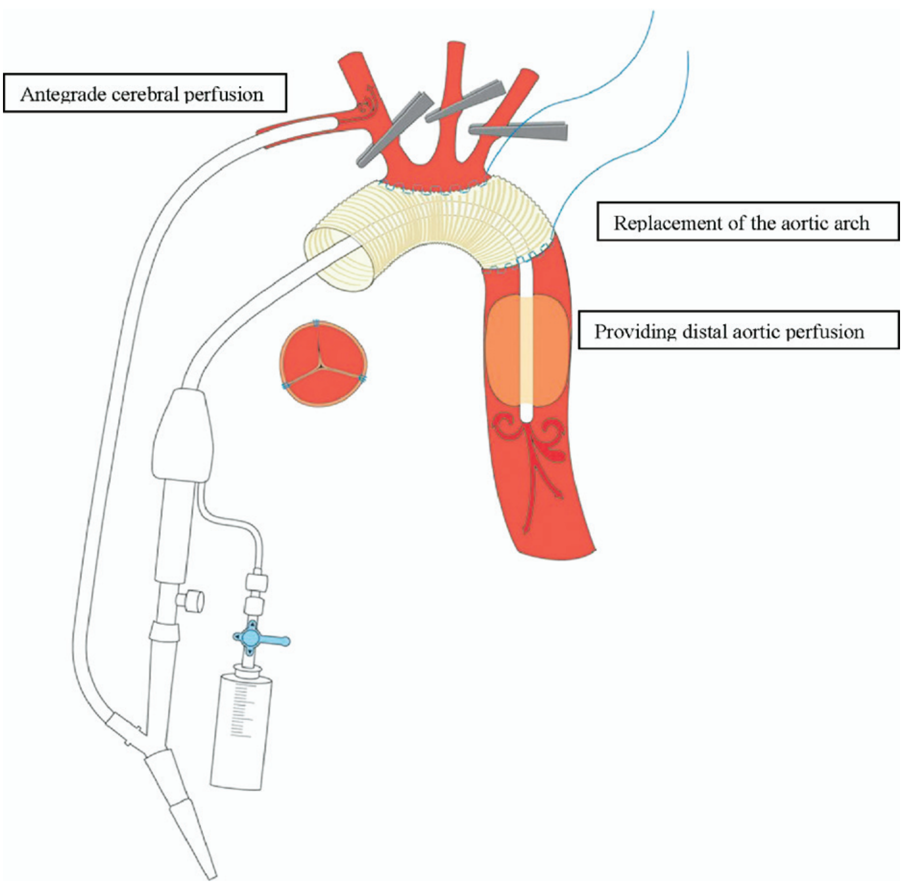

Figure 1. Application of the new cannula in an aortic arch surgery model with selective perfusion of the subclavian artery and intestine.

(Edwards Lifescience, Irvine, Calif). Our standard cardiopulmonary bypass (CPB) circuit includes a membrane oxygenator (Avant Physio, Dideco Stöckert, München, Germany) and heat exchanger (Jostra AG, Hirrlingen, Germany).

CPB is started, and the heart is arrested with intermittent retrograde and selective antegrade cold blood cardioplegia. Cooling is limited to 30°C rectal temperature. The innominate and left common carotid arteries are snared with elastic loops and occluded at the time of initiation of the antegrade cerebral perfusion (ACP) to prevent backflow and thus cerebral steal phenomena. If necessary, the left subclavian artery is blocked with a Fogarty catheter. ACP is conducted with a 30°C arterial perfusate flow in a pressure-controlled manner at a maximum of 75 mm Hg. After transaction of the aorta distal to the subclavian artery, the new cannula (Joline) will be inserted into the descending aorta for protection of the spinal cord and the abdominal organs. Then the balloon is inflated, and distal 30°C perfusion is achieved with a flow of 500 until 100 mL. Blood pressure levels for the distal perfusion are maintained at 50 mm Hg. Balloon occlusion of the descending aorta provides a bloodless surgical field and optimal conditions for suturing the aortic anastomosis. Aortic arch resection and replacement are performed with standard techniques depending on the underlying disease, with almost no time limitation. After distal and arch anastomosis, the cannula will be removed from the descending aorta, and proximal repair of the aorta follows during rewarming. The patient is placed in a head-down position, deairing is performed, and finally the prosthetic graft is clamped just proximally to the innominate artery. At this point, the elastic loops around the innominate and left common carotid arteries are released, and the arterial flow is returned to full-body perfusion. The decision making regarding proximal repair strategy is mostly based on the surgical inspection of the involvement of the aortic root, aortic valve, and coronary ostia.

Results

Ten patients (7 male and 3 female patients) underwent operative treatment of the diseased aortic arch because of chronic aneurysm involvement (n = 6, 60%) or acute dissection (n = 4, 40%). Table 1 contains patient characteristics, and Table 2 shows the operative and postoperative data and complications. Only one patient died on the 14th postoperative day because of intestinal bleeding with a history of ulcus ventriculi after an initial uncomplicated postoperative course. No patient experienced permanent neurological deficits, acute renal failure, or significant intestinal organ malfunction.

Discussion

Adequate perfusion of the abdominal organs, spinal cord, and lower extremities remains a great challenge in the treatment of the diseased aortic arch, especially if deep hypothermic circulatory arrest is avoided. The described new perfusion technique with a novel cannula for distal perfusion allows aortic arch procedures at mild hypothermia with preservation of distal organ function.

Initial experience with this technique demonstrated simple handling of the cannula, safety of the perfusion technique, and promising clinical results, with no significant impairment of spinal chord, renal, or intestinal organ function in the first 10 patients. Based on these experiences, we started to use this perfusion technique with 30°C mild systemic hypothermia together with ACP as our standard for aortic arch operations. In avoiding ischemia and deep hypothermia, this technique might help to reduce CPB time and deep hypothermia–related side effects.

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Alternative approach for stent grafting of the thoracic descending aorta: The antegrade right axillary approach

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Endovascular procedures are new options for high-risk patients presenting with a pathologic condition of the descending thoracic aorta. We report the case of a patient who underwent stent grafting of the descending thoracic aorta to treat a symptomatic penetrating ulcer. Because a conventional femoral approach was impossible, an antegrade right axillary approach was used.

Clinical Summary

A 53-year-old man was referred to us with a progressing intramural hematoma associated with a penetrating aortic ulcer of the descending thoracic aorta (T7-T8 level; Figure 1, *A-E*). Despite optimal medical therapy, the patient remained symptomatic, and 3 consecutive computed tomographic (CT) scans performed at 1-week intervals confirmed the progression of the ulcer. Because of the patient's chronic obstructive pulmonary disease, left ventricular dysfunction, and chronic occlusion of the infrarenal aorta (Figure 1, *F*), conventional open-chest surgery was judged to be prohibitive. Two different stent grafting strategies were considered. The first option was to proceed to a classic retrograde stent graft delivery after an aortobi-iliac bypass, and the second was to deliver the stent graft in an antegrade fashion through the right axillary artery approach. The patient did not complain of significant claudication and refused conventional abdominal surgery. Axillary and subclavian arteries were patent, with diameters ranging between 8.5 and 9 mm (Figure 1, *G*). The CT scan revealed no significant atheromatous lesions on the aortic arch, and hence the second option was selected. The procedure was performed after the patient underwent general anesthesia. Digital subtraction angiography and transesophageal echocardiographic guidance were used. Before stent positioning, an aortography was performed through the left brachial artery with a pigtail catheter (Cordis; Johnson & Johnson, Warren, NJ). After intravenous administration of 5000 IU of heparin, the right axillary artery was dissected out, and a 10-mm Dacron conduit was sutured in a terminolateral fashion. The 22F delivery system (Valiant Medtronic, Minneapolis, Minn) was introduced by the axillary conduit on a 260-cm-long superstiff guide wire (Back-Up Meier; Boston Scientific, Oakland, NJ; Figure 1, *H*

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